

Dilution and Tagging Power εD^2 for Same-Side Tagging for B_s Mesons (D0 Note 5155)

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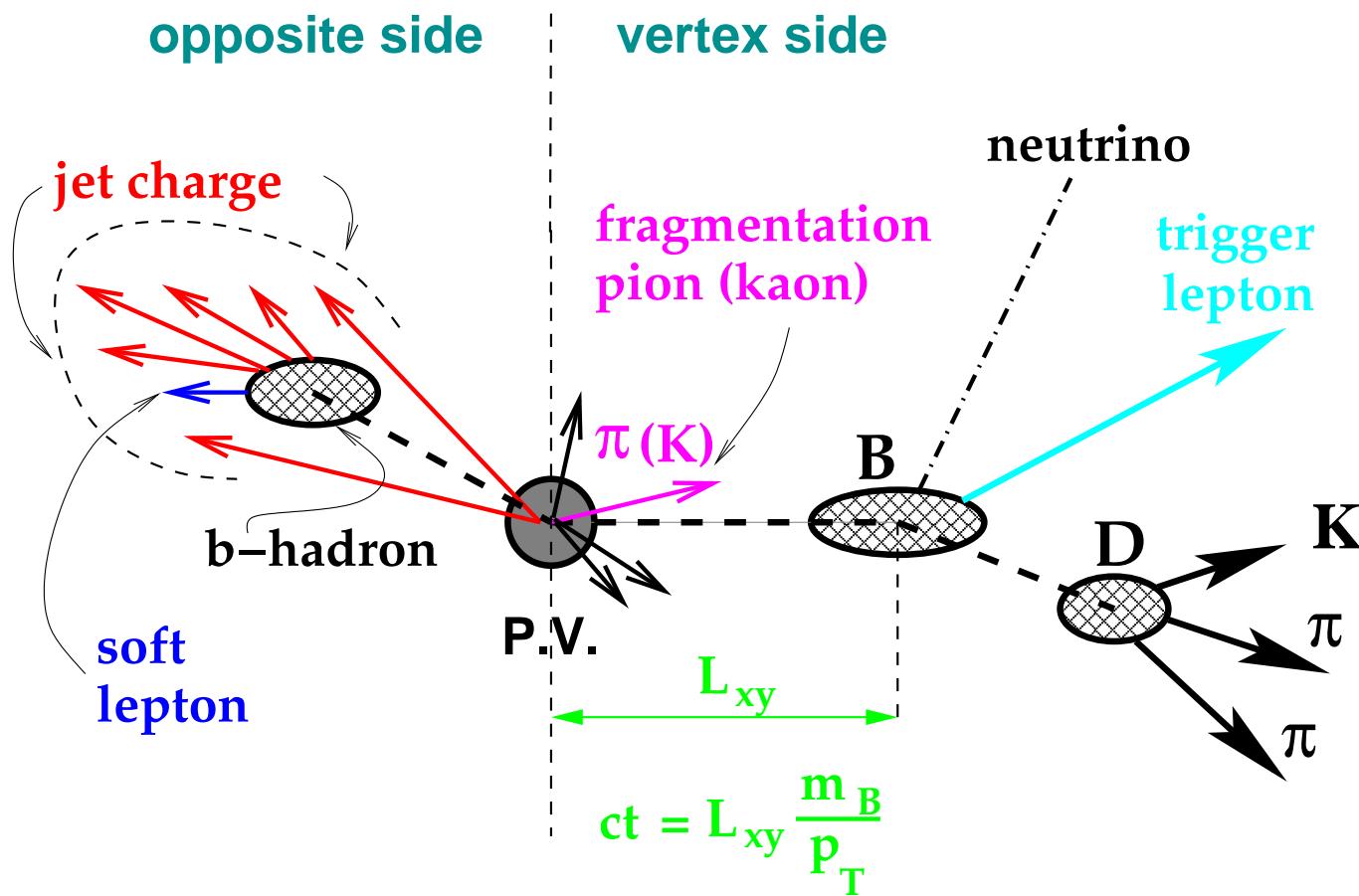
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 B -mixing and Lifetime Meeting

http://www-d0.fnal.gov/~rakitin/d0_private/tex/2006.Jun.29.Bmix/tr.pdf

Short introduction

To know if B -meson oscillated we need to know

- B -flavor at decay \Leftarrow can be inferred from trigger lepton charge
- B -flavor at production \Leftarrow obtained from OST (jet-charge, soft-lepton) or SST



I am going to talk about different SST methods and their combination with OST

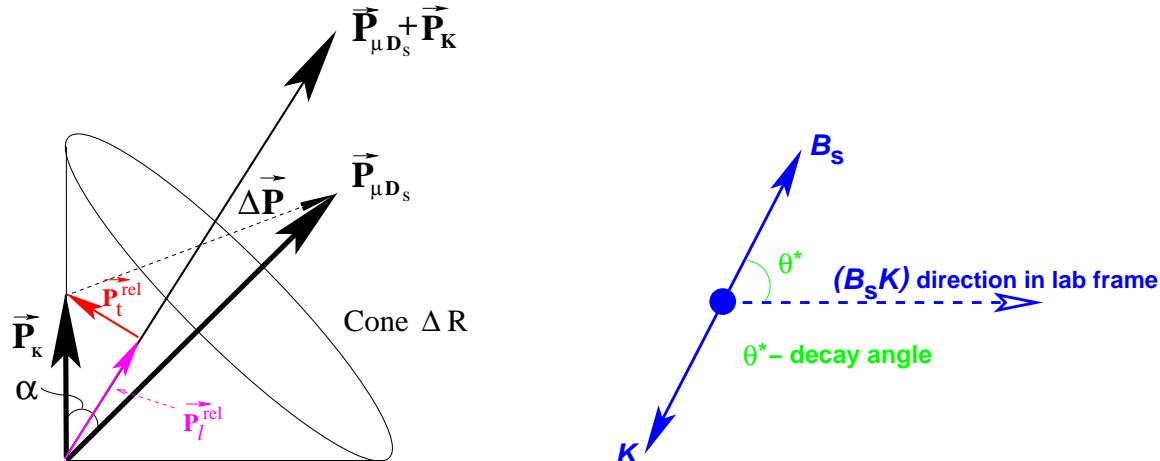
Outline of the analysis:

- Reconstruct B_s in p17 MC sample $B_s \rightarrow \mu D_s, D_s \rightarrow \phi\pi, (x_s = 25)$ (requests 29892, 29893)
- Look at tracks in cone $\cos\alpha < 0.8$ around $\vec{p}(B_s)$ (for consistency with OST)
- Use one of the following for same-side tagging:
 - Charge of one track selected with some kinematic (9 one-track taggers)
 - Charges of kaons coming from K^{*0} or pions from Λ (3 two-track taggers)
 - Aver. charge of all tracks around $\vec{p}(B)$, like “jet-charge” (31 many-track taggers)
- Apply each tagger together with “Comb. OST” to data and compute total εD^2

One-track taggers:

Nine taggers are used:

- | | | |
|---------------------------|--|------------------------|
| ☞ Min. p_t^{rel} | ☞ Min. $ \Delta \vec{P} \equiv \vec{p}(B_s) - \vec{p}(K) $ | ☞ Min. $\cos \theta^*$ |
| ☞ Max. p_L^{rel} | ☞ Min. ΔR | ☞ Max. $\cos \theta^*$ |
| ☞ Max. p_t | ☞ Max. $\cos \alpha$ | ☞ Min. $m(B_s K)$ |



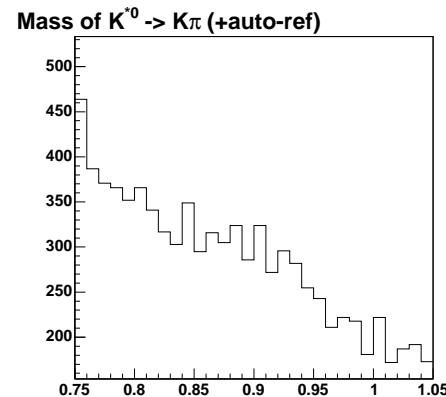
- p_t^{rel} and p_L^{rel} are \perp and $||$ components of SST candidate's momentum $\vec{p}(K)$ w.r.t $\vec{p}(B_s K)$
- $\Delta R \equiv \sqrt{\Delta\phi^2 + \Delta\eta^2}$ and angle α are taken between $\vec{p}(B_s)$ and $\vec{p}(K)$
- θ^* – decay angle of $B_s K$ -system, i.e. angle between directions of $\vec{p}(B_s K)$ and $\vec{p}(B_s)$ in reference frame of $B_s K$ system

Two-track taggers:

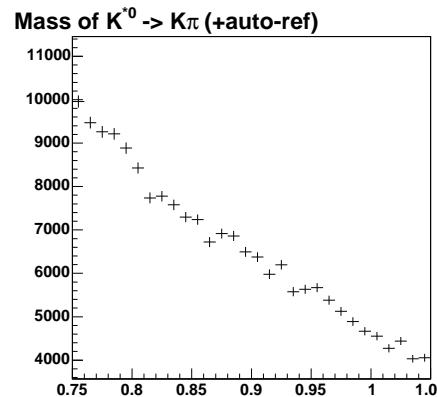
Using charge of kaon coming from $K^{*0} \rightarrow K\pi$ and $\Lambda \rightarrow p\pi$:

- ☞ Reconstruct $0.842 < m(K^{*0} \rightarrow K\pi) < 0.942$
with auto-reflection being outside of this mass window,
so that we know which track is kaon
- ☞ Apply cuts to reconstruction of $K^{*0} \rightarrow K\pi$
 - see if they improve tagging performance
- ☞ Reconstruct $\Lambda \rightarrow p\pi^-$ and $\bar{\Lambda} \rightarrow \bar{p}\pi^+$
 - Particles reconstructed out of tracks in cone $\cos \alpha > 0.8$
 - B_s daughters are, obviously, excluded

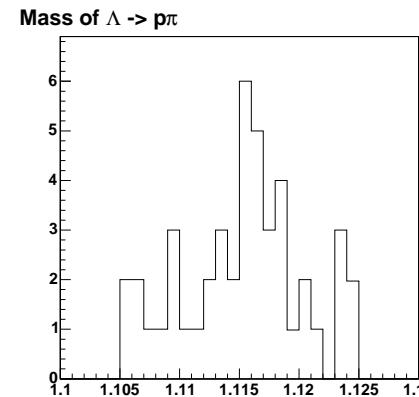
Monte Carlo



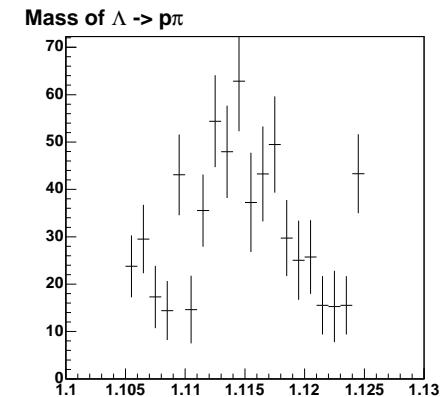
Data



Monte Carlo



Data



Many-track taggers:

Using weighted-average charge of all the tracks around $\vec{p}(B_s)$

Thirty-one tagger used:

$$\begin{aligned}\Leftrightarrow Q_{jet}(p_t, \kappa) &= \frac{\sum q \cdot p_t^\kappa}{\sum p_t^\kappa} \\ \Leftrightarrow Q_{jet}(p_t^{rel}, \kappa) &= \frac{\sum q \cdot (p_t^{rel})^\kappa}{\sum (p_t^{rel})^\kappa} \\ \Leftrightarrow Q_{jet}(p_L^{rel}, \kappa) &= \frac{\sum q \cdot (p_L^{rel})^\kappa}{\sum (p_L^{rel})^\kappa}\end{aligned}$$

- $\kappa = 0.0, 0.1, 0.2, \dots 1.0$
- p_t^{rel} and p_L^{rel} here are \perp and \parallel components of SST candidate's momentum $\vec{p}(K)$ w.r.t $\vec{p}(B_s)$

Obtaining *true dilution* in MC

For each tagger we measure numbers of events in which:

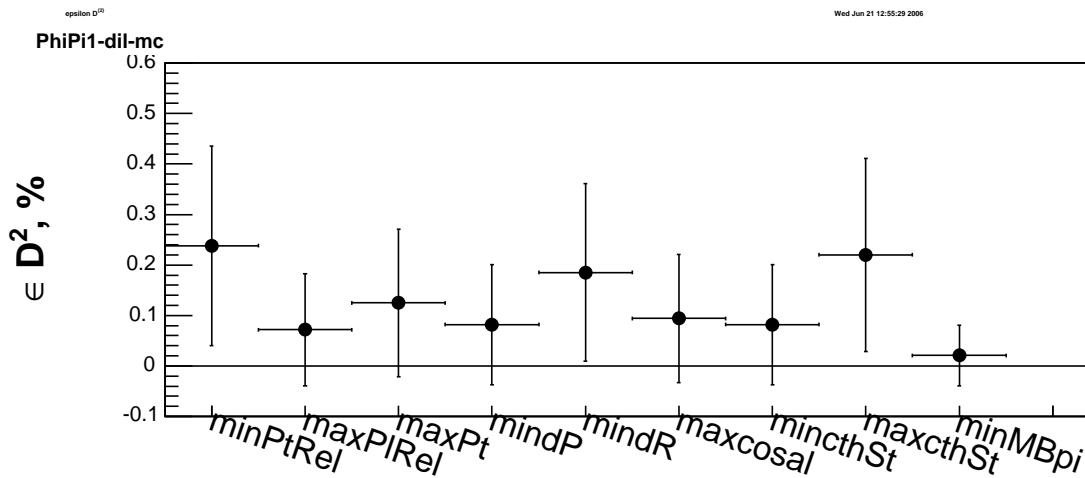
- tag charge corresponds to true B_d -flavor at production (“Right Tag”)
- tag charge is opposite to true B_d -flavor at production (“Wrong Tag”)
- no tag was found (“No Tag”)

$$\text{Mistag rate } p = \frac{N_{WT}}{N_{RT} + N_{WT}}$$

$$\text{True dilution } D = 1 - 2p = \frac{N_{RT} - N_{WT}}{N_{RT} + N_{WT}}$$

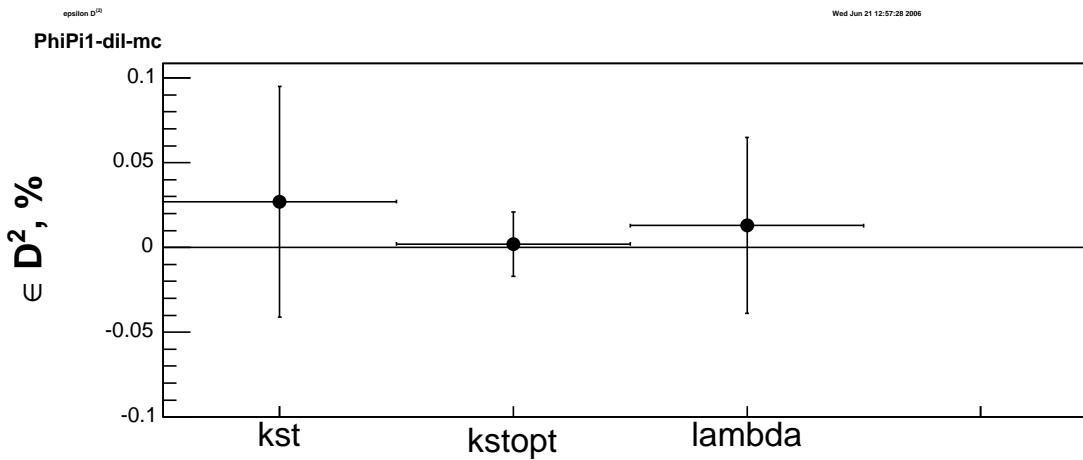
True dilutions in MC - one-track taggers

Tagger	RT	WT	NT	$\varepsilon, \%$	D, %	$\varepsilon D^2, \%$
Min. p_t^{rel}	1043 ± 32	941 ± 31	217 ± 15	90.1 ± 0.6	5.1 ± 2.2	0.238 ± 0.198
Max. p_L^{rel}	1020 ± 32	964 ± 31	217 ± 15	90.1 ± 0.6	2.8 ± 2.2	0.072 ± 0.111
Max. p_t	1029 ± 32	955 ± 31	217 ± 15	90.1 ± 0.6	3.7 ± 2.2	0.125 ± 0.146
Min. $ \Delta \vec{P} $	1022 ± 32	962 ± 31	217 ± 15	90.1 ± 0.6	3.0 ± 2.2	0.082 ± 0.119
Min. ΔR	1037 ± 32	947 ± 31	217 ± 15	90.1 ± 0.6	4.5 ± 2.2	0.185 ± 0.176
Max. $\cos \alpha$	1024 ± 32	960 ± 31	217 ± 15	90.1 ± 0.6	3.2 ± 2.2	0.094 ± 0.127
Min. $\cos \theta^*$	1022 ± 32	962 ± 31	217 ± 15	90.1 ± 0.6	3.0 ± 2.2	0.082 ± 0.119
Max. $\cos \theta^*$	1041 ± 32	943 ± 31	217 ± 15	90.1 ± 0.6	4.9 ± 2.2	0.220 ± 0.191
Min. $m(B_s K)$	1007 ± 32	977 ± 31	217 ± 15	90.1 ± 0.6	1.5 ± 2.2	0.021 ± 0.060



True dilutions in MC - two-track taggers

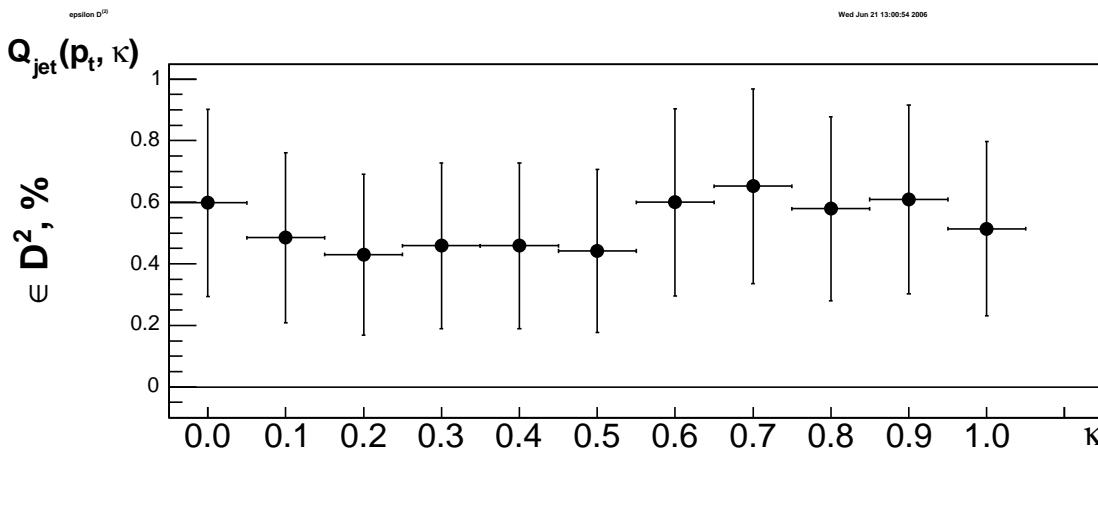
Tagger	RT	WT	NT	$\varepsilon, \%$	D, %	$\varepsilon D^2, \%$
$K^{*0} \rightarrow K\pi$	349 ± 19	329 ± 18	1523 ± 39	30.8 ± 1.0	2.9 ± 3.8	0.027 ± 0.068
$K^{*0} \rightarrow K\pi(\text{opt})$	46 ± 7	48 ± 7	2107 ± 46	4.3 ± 0.4	-2.1 ± 10.3	0.002 ± 0.019
Λ	6 ± 2	8 ± 3	2187 ± 47	0.6 ± 0.2	-14.3 ± 26.5	0.013 ± 0.052



True dilutions in MC - many-track taggers

Weighted with p_t :

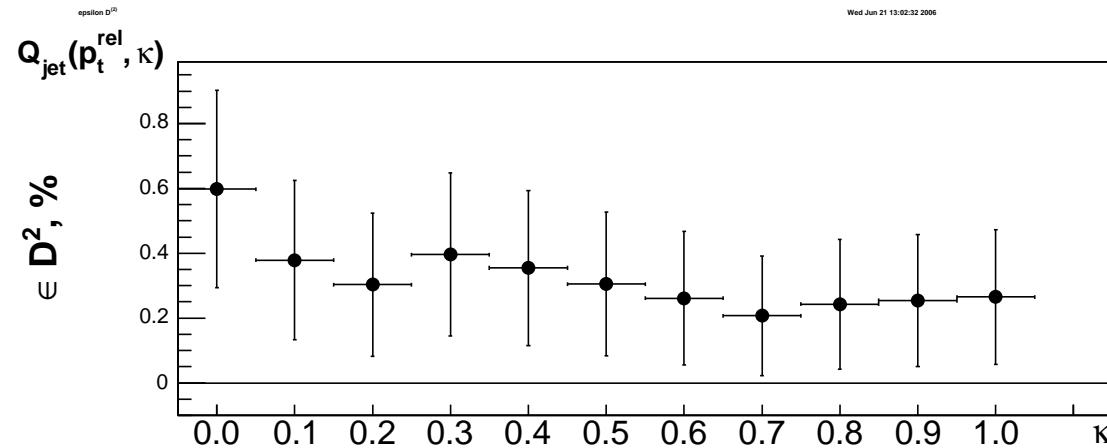
Tagger	RT	WT	NT	$\varepsilon, \%$	D, %	$\varepsilon D^2, \%$
Aver. Q	760 ± 28	625 ± 25	816 ± 29	62.9 ± 1.0	9.7 ± 2.7	0.598 ± 0.304
$Q_{jet}(p_t, \kappa = 0.1)$	711 ± 27	593 ± 24	897 ± 30	59.2 ± 1.0	9.0 ± 2.8	0.485 ± 0.276
$Q_{jet}(p_t, \kappa = 0.2)$	706 ± 27	595 ± 24	900 ± 30	59.1 ± 1.0	8.5 ± 2.8	0.430 ± 0.261
$Q_{jet}(p_t, \kappa = 0.3)$	712 ± 27	597 ± 24	892 ± 30	59.5 ± 1.0	8.8 ± 2.8	0.459 ± 0.269
$Q_{jet}(p_t, \kappa = 0.4)$	724 ± 27	608 ± 25	869 ± 29	60.5 ± 1.0	8.7 ± 2.7	0.459 ± 0.269
$Q_{jet}(p_t, \kappa = 0.5)$	737 ± 27	622 ± 25	842 ± 29	61.7 ± 1.0	8.5 ± 2.7	0.442 ± 0.264
$Q_{jet}(p_t, \kappa = 0.6)$	758 ± 28	623 ± 25	820 ± 29	62.7 ± 1.0	9.8 ± 2.7	0.600 ± 0.304
$Q_{jet}(p_t, \kappa = 0.7)$	774 ± 28	632 ± 25	795 ± 28	63.9 ± 1.0	10.1 ± 2.7	0.652 ± 0.316
$Q_{jet}(p_t, \kappa = 0.8)$	782 ± 28	647 ± 25	772 ± 28	64.9 ± 1.0	9.4 ± 2.6	0.579 ± 0.299
$Q_{jet}(p_t, \kappa = 0.9)$	801 ± 28	661 ± 26	739 ± 27	66.4 ± 1.0	9.6 ± 2.6	0.609 ± 0.306
$Q_{jet}(p_t, \kappa = 1.0)$	812 ± 28	682 ± 26	707 ± 27	67.9 ± 1.0	8.7 ± 2.6	0.514 ± 0.283



True dilutions in MC - many-track taggers

Weighted with p_t^{rel} :

Tagger	RT	WT	NT	$\varepsilon, \%$	D, %	$\varepsilon D^2, \%$
Aver. Q	760 ± 28	625 ± 25	816 ± 29	62.9 ± 1.0	9.7 ± 2.7	0.598 ± 0.304
$Q_{jet}(p_t^{rel}, \kappa = 0.1)$	700 ± 26	596 ± 24	905 ± 30	58.9 ± 1.0	8.0 ± 2.8	0.379 ± 0.246
$Q_{jet}(p_t^{rel}, \kappa = 0.2)$	694 ± 26	601 ± 25	906 ± 30	58.8 ± 1.0	7.2 ± 2.8	0.303 ± 0.221
$Q_{jet}(p_t^{rel}, \kappa = 0.3)$	711 ± 27	604 ± 25	886 ± 30	59.7 ± 1.0	8.1 ± 2.7	0.396 ± 0.251
$Q_{jet}(p_t^{rel}, \kappa = 0.4)$	730 ± 27	627 ± 25	844 ± 29	61.7 ± 1.0	7.6 ± 2.7	0.355 ± 0.239
$Q_{jet}(p_t^{rel}, \kappa = 0.5)$	750 ± 27	653 ± 26	798 ± 28	63.7 ± 1.0	6.9 ± 2.7	0.305 ± 0.222
$Q_{jet}(p_t^{rel}, \kappa = 0.6)$	766 ± 28	675 ± 26	760 ± 28	65.5 ± 1.0	6.3 ± 2.6	0.261 ± 0.206
$Q_{jet}(p_t^{rel}, \kappa = 0.7)$	779 ± 28	697 ± 26	725 ± 27	67.1 ± 1.0	5.6 ± 2.6	0.207 ± 0.185
$Q_{jet}(p_t^{rel}, \kappa = 0.8)$	803 ± 28	713 ± 27	685 ± 26	68.9 ± 1.0	5.9 ± 2.6	0.243 ± 0.200
$Q_{jet}(p_t^{rel}, \kappa = 0.9)$	821 ± 29	728 ± 27	652 ± 26	70.4 ± 1.0	6.0 ± 2.5	0.254 ± 0.204
$Q_{jet}(p_t^{rel}, \kappa = 1.0)$	839 ± 29	743 ± 27	619 ± 25	71.9 ± 1.0	6.1 ± 2.5	0.265 ± 0.208

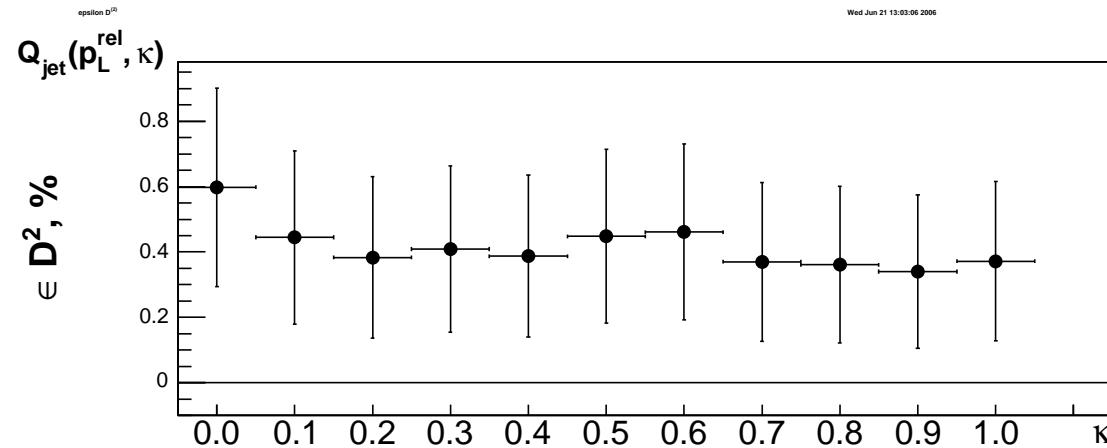


Best $\kappa = 0.0$

True dilutions in MC - many-track taggers

Weighted with p_L^{rel} :

Tagger	RT	WT	NT	$\varepsilon, \%$	D, %	$\varepsilon D^2, \%$
Aver. Q	760 ± 28	625 ± 25	816 ± 29	62.9 ± 1.0	9.7 ± 2.7	0.598 ± 0.304
$Q_{jet}(p_L^{rel}, \kappa = 0.1)$	709 ± 27	596 ± 24	896 ± 30	59.3 ± 1.0	8.7 ± 2.8	0.445 ± 0.265
$Q_{jet}(p_L^{rel}, \kappa = 0.2)$	707 ± 27	602 ± 25	892 ± 30	59.5 ± 1.0	8.0 ± 2.8	0.383 ± 0.247
$Q_{jet}(p_L^{rel}, \kappa = 0.3)$	715 ± 27	606 ± 25	880 ± 30	60.0 ± 1.0	8.3 ± 2.7	0.409 ± 0.255
$Q_{jet}(p_L^{rel}, \kappa = 0.4)$	725 ± 27	618 ± 25	858 ± 29	61.0 ± 1.0	8.0 ± 2.7	0.387 ± 0.248
$Q_{jet}(p_L^{rel}, \kappa = 0.5)$	740 ± 27	624 ± 25	837 ± 29	62.0 ± 1.0	8.5 ± 2.7	0.448 ± 0.266
$Q_{jet}(p_L^{rel}, \kappa = 0.6)$	757 ± 28	638 ± 25	806 ± 28	63.4 ± 1.0	8.5 ± 2.7	0.461 ± 0.269
$Q_{jet}(p_L^{rel}, \kappa = 0.7)$	757 ± 28	650 ± 25	794 ± 28	63.9 ± 1.0	7.6 ± 2.7	0.370 ± 0.243
$Q_{jet}(p_L^{rel}, \kappa = 0.8)$	774 ± 28	667 ± 26	760 ± 28	65.5 ± 1.0	7.4 ± 2.6	0.361 ± 0.240
$Q_{jet}(p_L^{rel}, \kappa = 0.9)$	789 ± 28	684 ± 26	728 ± 27	66.9 ± 1.0	7.1 ± 2.6	0.340 ± 0.234
$Q_{jet}(p_L^{rel}, \kappa = 1.0)$	807 ± 28	696 ± 26	698 ± 26	68.3 ± 1.0	7.4 ± 2.6	0.372 ± 0.244



Best $\kappa = 0.0$

Q: Why are we showing untuned MC values for the dilution?

A: This is MC available at the moment. We don't have to present these dilutions anywhere, so should we really tune it?

Using double-tagged events

Use uncorrelated taggers: “Comb. OST” (developed previously) and one of SSTs to:

- ☞ Measure SST dilution directly from data
- ☞ Compute combined tagging power ϵD^2

Q: Doing this would amount to using the same B_s data set twice: first to get a functional form of the SST dilution vs. tagging variable after which this dilution calibration would be used on the same data set to extract Δm_s .

A: We can use the double-tagged events for calibration purposes only, while for the extraction of Δm_s we can consider these events as only OST-tagged (because we trust OST more) and the rest of the events as SST-tagged.

Using double-tagged events

Algorithm:

- Divide sample into five subsamples:
 - N_1 events tagged only by first tagger with *true* dilution D_1
 - N_2 events tagged only by second tagger with *true* dilution D_2
 - N_{12} events tagged by both taggers identically with *true* dilution $D_{12} = \frac{D_1+D_2}{1+D_1D_2}$
 - \bar{N}_{12} events tagged by both taggers differently with *true* dilution $\bar{D}_{12} = \frac{|D_1-D_2|}{1-D_1D_2}$
 - \bar{N}_{NT} events not tagged by both taggers
- A simple formula holds: $D_1D_2 = \frac{N_{12}-\bar{N}_{12}}{N_{12}+\bar{N}_{12}}$ (see Appendix B of D0 Note 5155)
- Use one (more trustworthy) *true* dilution from other sources and measure another (D0 Note 4991: $D_{OST} = 44.3 \pm 2.2\%$)
- Note: Calculate dilution $\mathcal{D} = \frac{N_1D_1+N_2D_2+N_{12}D_{12}+\bar{N}_{12}\bar{D}_{12}}{N_{\text{tagged}}}$
- Note: Calculate tagging efficiency $\epsilon = \frac{N_{\text{tagged}}}{N_{\text{total}}}$
- Update to note: Compute $\varepsilon D^2 = \frac{N_1}{N}D_1^2 + \frac{N_2}{N}D_2^2 + \frac{N_{12}}{N}D_{12}^2 + \frac{\bar{N}_{12}}{N}\bar{D}_{12}^2 \neq \epsilon \mathcal{D}^2$

Combination SST + OST in $\phi\pi$ data

	N_1	N_2	N_{NT}	N_{12}	\bar{N}_{12}	$\frac{N_{12}-\bar{N}_{12}}{N_{12}+\bar{N}_{12}}$	D_{OST}	D_{SST}^{meas}	D_{12}^{calc}	\bar{D}_{12}^{calc}	$\varepsilon D^2(\text{calc}), \%$
Min. p_t^{rel}	21944±200	277±19	2090±53	1483±51	1478±50	0.002±0.024	44.3 ± 2.2	0.4±5.4	44.6±4.9	44.0±4.9	2.332±0.338
Max. p_L^{rel}	21944±200	277±19	2090±53	1560±52	1391±49	0.057±0.024	44.3 ± 2.2	12.9±5.5	54.1±4.4	33.3±5.5	3.785±1.185
Max. p_t	21944±200	277±19	2090±53	1538±51	1408±49	0.044±0.024	44.3 ± 2.2	9.9±5.5	52.0±4.5	35.9±5.4	3.187±0.936
Min. $ \Delta\vec{P} $	21944±200	277±19	2090±53	1551±52	1399±49	0.052±0.024	44.3 ± 2.2	11.7±5.5	53.2±4.4	34.4±5.4	3.516±1.080
Min. ΔR	21944±200	277±19	2090±53	1574±52	1377±49	0.067±0.024	44.3 ± 2.2	15.1±5.5	55.7±4.3	31.3±5.6	4.316±1.370
Max. $\cos\alpha$	21944±200	277±19	2090±53	1583±52	1371±48	0.072±0.024	44.3 ± 2.2	16.2±5.5	56.4±4.3	30.3±5.7	4.619±1.461
Min. $\cos\theta^*$	21944±200	277±19	2090±53	1569±52	1382±49	0.063±0.024	44.3 ± 2.2	14.3±5.5	55.1±4.3	32.1±5.6	4.107±1.302
Max. $\cos\theta^*$	21944±200	277±19	2090±53	1488±51	1476±50	0.004±0.024	44.3 ± 2.2	0.9±5.4	45.0±4.8	43.6±4.9	2.339±0.345
Min. $m(B_s K)$	21944±200	277±19	2090±53	1521±51	1442±49	0.027±0.024	44.3 ± 2.2	6.0±5.4	49.0±4.6	39.3±5.1	2.650±0.621
Aver. Q	15415±164	1111±43	8639±125	1096±42	1027±40	0.032±0.027	44.3 ± 2.2	7.3±6.2	50.0±5.1	38.2±5.8	2.654±0.582
$Q_{jet}(p_t, \kappa=0.7)$	15630±166	1121±43	8419±124	1119±43	988±40	0.062±0.028	44.3 ± 2.2	14.1±6.3	55.0±4.9	32.2±6.2	3.560±1.051
$K^{*0} \rightarrow K\pi$	7720±126	2271±60	16327±164	482±30	482±29	-0.000±0.043	44.3 ± 2.2	-0.0±9.8	44.3±8.2	44.3±8.2	2.327±0.248

These εD^2 's are for combined SST + OST and cannot be directly compared to εD^2 's from MC, which are for SST only.

These numbers are updated w.r.t. Note 5155, because formula for εD^2 in Appendix B was corrected.

Q: The SST dilution extracted using the double-tagging technique is fully correlated with the OST dilution value used.

A: This effect can be taken into account in the systematics

Summary

- Investigated several SST algorithms:
 - for p17 Monte Carlo $B_s \rightarrow \mu D_s, D_s \rightarrow \phi\pi$ ($x_s = 25$)
 - for data in [`/prj_root/1008/ckm_write/bgv/evt/muphiipi-std/`](#)
- Divided taggers into three groups: 9 one-track taggers, 3 two-track taggers, 31 many track taggers
- Obtained dilution and εD^2 for each tagger in MC
- Used both SST and OST on data \implies measured SST dilution **purely from data**:
 - “Max. $\cos \alpha$ ” method has the best dilution $D = 16.2 \pm 5.5 \%$
 - Corresponding tagging power $\varepsilon D^2 = 4.619 \pm 1.461 \%$
- Need to have more consistency in the data